Radiation Physics Note No. 84

Radionuclide Emission from the AP0 Stack During Calendar Year 1989

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The Tevatron collider program was operated during approximately the first 152 days of 1989. During that period, the weekly Accelerator Division operating summaries indicate that a total of 5.821×10^{18} protons were targeted on the AP0 target. This run constituted the only operation of this target station during 1989. During this period of time the radionuclide emissions from this target station were continuously monitored by a Geiger-Müeller-based (GM) gas sampling system described in Butala *et al* [1]. Counts from this detector were recorded by the Fermilab MUX system throughout the collider physics run during 1989.

Measurements made by Butala *et al* [2] used to provide background data for the investigation described in Ref. 1 resulted in an assessment of the radioactivity calibration factor appropriate for the particular GM detector used at the AP0 Stack. This factor was determined to be 0.023 pCi/ml/ct/hr. The output of the blower fan at this stack is 2000 ft^3/minute. Doing the appropriate unit conversions as follows, one can obtain a conversion factor in terms of Curies/ GM ct:

$$\frac{0.023\ \text{pCi}}{\text{ml}}\frac{\text{hr}}{\text{ct}} \times \frac{60\ \text{min}}{\text{hr}} \times \frac{2000\text{ft}^3}{\text{min}} \times \frac{28316.8\ \text{ml}}{\text{ft}^3} = \frac{7.815 \times 10^7 \text{pCi}}{\text{ct}} = \frac{7.815 \times 10^{-5} \text{Ci}}{\text{ct}}.$$

This conversion, then, can be used to obtain the airborne radioactivity release due to a given number of MUX counts from the GM detector after subtracting a nominal background counting rate (observed several times during this period during accelerator "down-times") of 11 counts/hr.

The MUX pulses were tabulated for the operational period along with the integrated beam intensities. On three occasion, various equipment problems caused the MUX system to fail to operate. Since the activity produced per given quantity of beam should approximately a constant subject to some fluctuations due to meteorological conditions, the number of net counts divided by the corresponding integrated beam intensity should provide a factor for using the integrated proton intensity to give an estimate of the MUX counts missed during such a period. This was done for 19 such periods during the run. The results are displayed on Fig. 1 where the MUX counts per 10^{16} protons are plotted as a function of the day of the year. The average was determined to be 1808.8

MUX counts per 10^{16} protons with a standard deviation of 614 counts per 10^{16} protons. The large fluctuations seen both during the first 50 days and the last 10 days may well be indicative of targeting adjustments being made to improve performance of the antiproton source. The average value was used to supply the MUX counts otherwise missed during MUX down-times. This correction was made for 12.3 % of the total protons targeted.

Figure 2 is a plot of the net counts/day (open circles) and the number of protons/day (filled circles) as a function of Day of the Year for this run. As one can see, the count rate follows the targeted intensities rather well, as expected from Fig. 1. The total number of net counts for the duration of the run is 1.049522 X 10^6 over a total number of hours of 3648. Thus, using the above conversion factor, 82.0 Curies of airborne radioactivity were released during the collider run. Using the results of Ref. 2, this was determined to be divided in the following manner:

Radionuclide	**Percentage (Ref.1)**		**Activity Released**
^{11}C	42		34.4
^{13}N	14		11.5
^{38}Cl	11		9.0
^{39}Cl	13		10.7
^{41}Ar	20		16.4
		Total	**82.0**

Of course, one must also consider concentrations of airborne radioactivity at the point of emission for such a source. The average number of net MUX counts recorded per day during the running period was 6906 with a standard deviation of 2666. This corresponds to the emission of 0.540 Curies/day (distributed among the radionuclides according to the above percentages) diluted with 2000 ft^3/minute of air (2.88 X 10^6 ft^3, or 8.16 X 10^{10} cm^3). Thus, the average total concentrations are about 0.187 X μCi/ft^3 or 6.6 pCi/cm^3. Peak emissions and concentrations ranged up to a factor of 1.9 higher.

Finally, it is interesting to note that the authors of Ref. 1 measured total radioactivity production rate of 0.5 μBq/incident proton at AP0 in a short term measurement. This corresponds, in more civilized units, to 1.35 X 10^{-17} Curies/incident proton. The measured production of 82.02 Curies during a collider run involving the targeting of 5.821 X 10^{18} represents a value 1.41 X 10^{-17} Curies per incident proton.

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References:

1. S. W. Butala, S. I. Baker, and P. M. Yurista, "Measurements of Radioactive Gaseous Releases to Air from Target Halls at a High-Energy Proton Accelerator", Health Physics 57(1989)909-916.

2. S. Butala, S. Baker, and P. Yurista, "AP0 Stack Monitor Calibration", Radiation Physics Note 70, April, 1988.

Figure 1

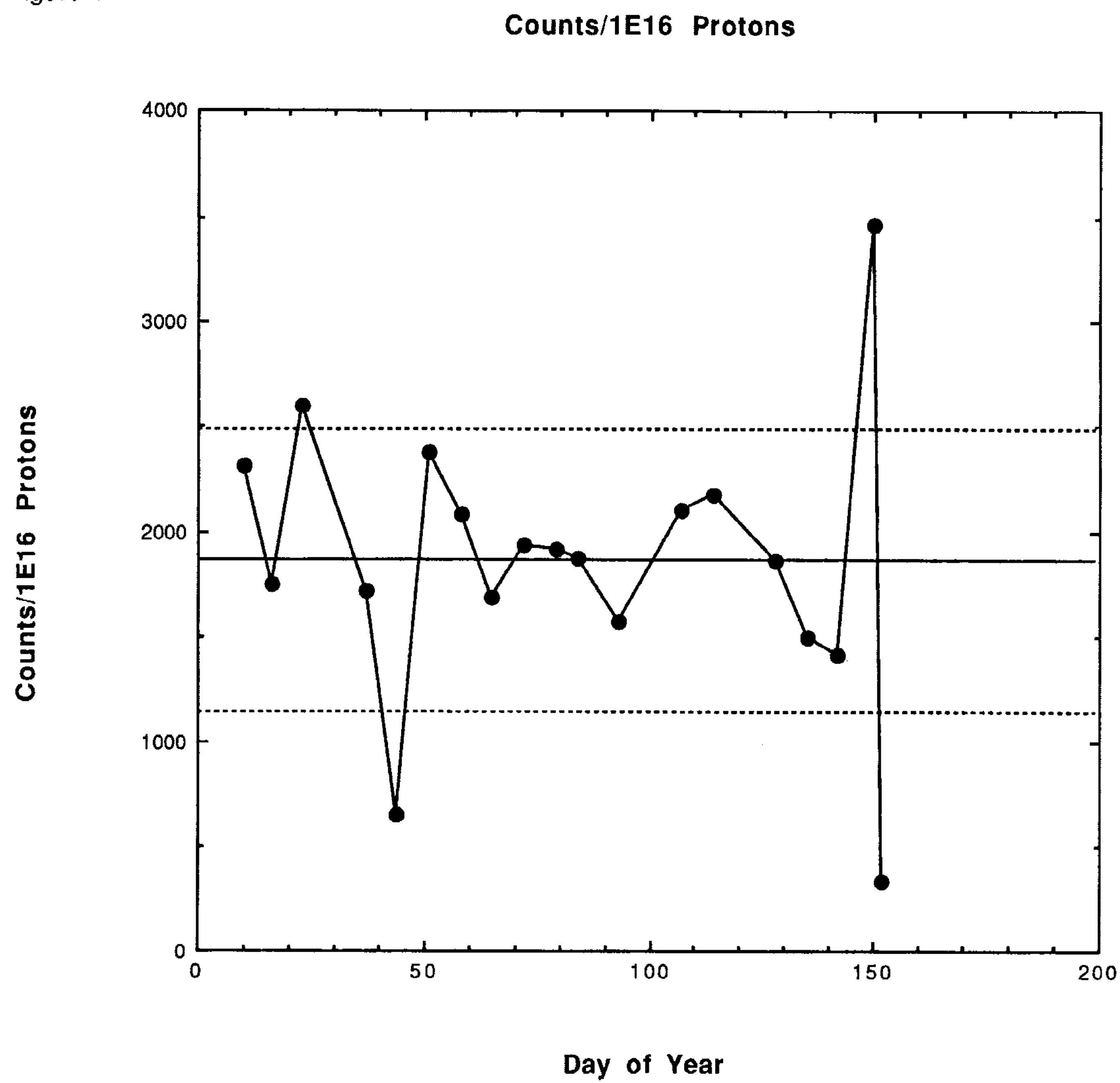
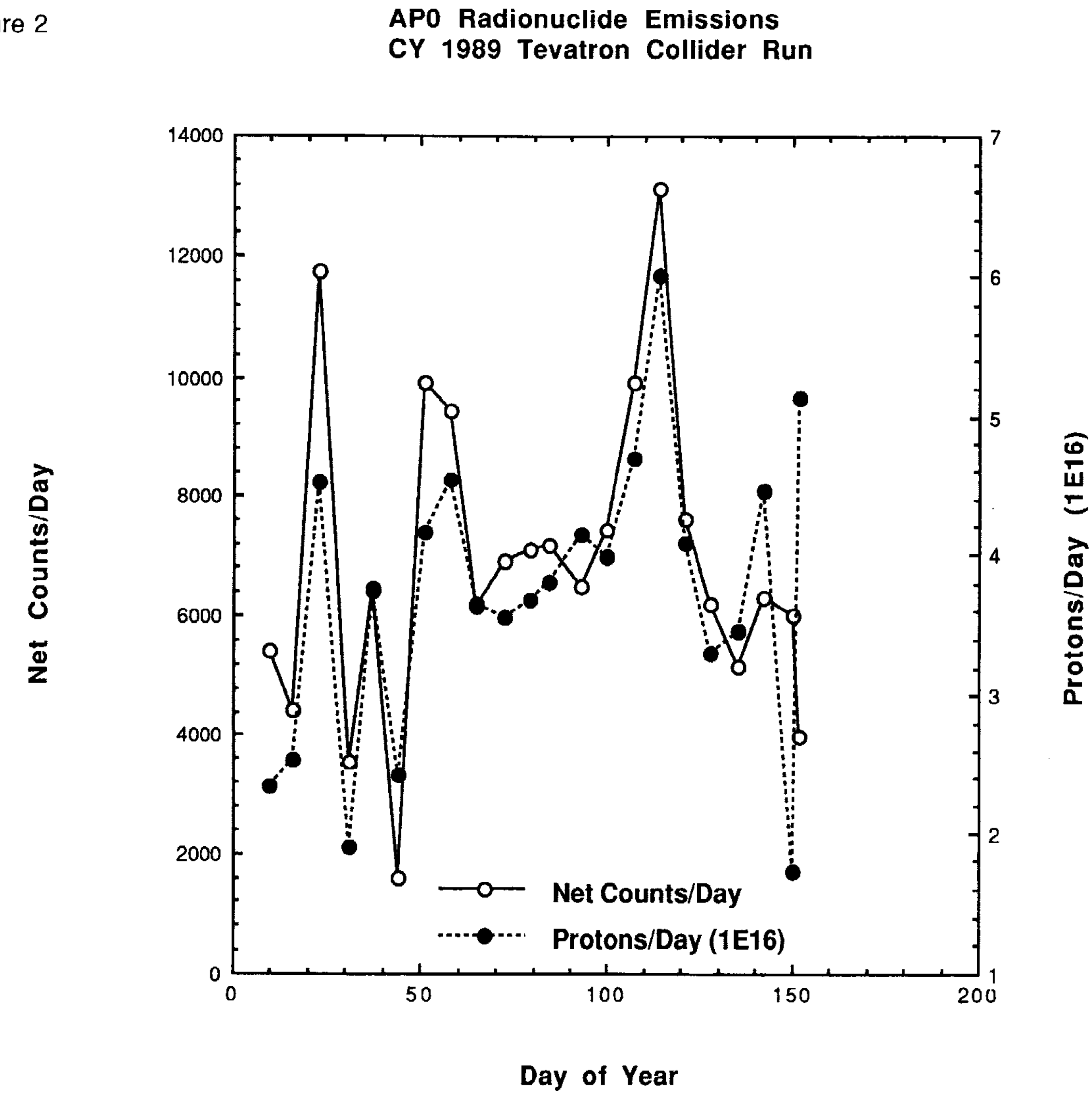

Counts/1E16 Protons
4000
3000
2000
1000
0
0
50
100
150
200
Counts/1E16 Protons
Day of Year

Figure 2



AP0 Radionuclide Emissions
CY 1989 Tevatron Collider Run
Net Counts/Day
Protons/Day (1E16)
Day of Year
0
2000
4000
6000
8000
10000
12000
14000
1
2
3
4
5
6
7
0
50
100
150
200